This can be achieved by providing a suitable combination of cell size and percentage open cells in the foam structure. Those having ordinary skill in the art will not have any undue difficulty in selecting appropriate reactants, catalysts, cell stabilizers, blowing agents and operating temperatures and pressures for achieving the porosity needed for achieving desired sound absorbing properties in the laminate.

[0029] Laminate 10 may be produced by advancing individual webs of material toward a thermoforming station. For example, webs of fibrous batt 12, reinforcing mats 16 and 18, and a web of release layer 24 may be brought together, after a suitable binding resin has been applied to at least one of the interfacing surfaces of adjacent layers. The liquid thermosetable binding resin can effect temporary adhesion between the layers prior to thermoforming. Likewise, a web of cover sheet 22 and a web of fibrous reinforcing batt 20 may be brought together after a suitable binding resin has been applied to at least one of the interfacing surfaces of adjacent layers 20 and 22. Again, the liquid thermosetable binding resin can act to form a temporary laminate which can be advanced to the thermoforming station. The temporary laminate comprising layers 20 and 22 can be cut to an appropriate size and placed in the lower portion of a thermoforming molding tool. Additional binding resin may be applied to the underside of rigid foam layer 14 or the top side of fibrous reinforcing layer 20, before rigid foam layer 14 is positioned over the temporary laminate comprising layers 20 and 22. Thereafter, the temporary laminate comprising webs of layers 24, 16, 12 and 18 can be cut to an appropriate size and positioned over rigid foam layer 14. Before positioning the temporary web comprising layers 24, 16, 12 and 18 over rigid foam layer 14, additional binding resin may be applied to the underside of fibrous reinforcing layer 18 and/or to the top side of rigid foam layer 14.

[0030] As an alternative, each of the individual layers can be cut to an appropriate size and stacked in an appropriate manner, with sufficient binding resin present between the interfacing surfaces of the adjacent layers. As another alternative, layers 16, 18 and 20 may be formed directly on an adjacent layer, as described above. Molding of laminate 10 to produce the shape of configured part 20 (FIG. 2) is effected under conditions of heat and pressure sufficient to effect curing of the thermosetable binding resin, to set the thermoformable fibers of fibrous batt layer 12 into their new shape and to compress those fibers at the laminate periphery, including the peripheries of any openings which may be formed in laminate 10, to form a dense unitary bond line. Any changes in the thicknesses of layers 24, 16, 18, 14, 20 and 22 brought about by the thermoforming operation do not appreciably effect the overall thickness of the finished article. However, during the thermoforming operation, the fibrous batt layer 12 can be compressed to a substantially reduced thickness. The thickness of layer 12 of the finished article will vary generally from about 1.5 to about 25 millimeters. During the thermoforming operation, the surfaces of the thermoforming molding tool are at an elevated temperature, such as about 130°C. The molding pressure, i.e., the amount of force applied to the upper half of the molding tool is approximately 150 to 225 metric tons per square meter.

[0031] A major advantage with the headliners and laminates of the present invention is that they may be designed, or tuned, to provide particularly enhanced sound absorption/deadening properties for selected frequency ranges. Specifically, it has been determined that laminate articles in accordance with the invention can be tuned for absorbing sounds at selected frequencies or selected frequency ranges by adjusting the porosity and/or density of the rigid foam layer 14. Porosity and density are not entirely mutually exclusive parameters. In particular, porosity tends to decrease as density increases. Porosity is also a function of cell size and the percentage of closed cells versus open cells. In general, better absorption of low frequency sounds can be achieved by providing the laminate of this invention with a rigid foam layer 14 having a relatively high density, relatively small cells, and a relatively high percentage of closed cells. When better sound absorbing properties are desired with respect to higher frequency sounds, layer 14 preferably has a relatively lower density, relatively larger cell sizes, and a relatively lower percentage of closed cells. The density of the rigid foam layer 14 can range from about 1.5 pounds per cubic foot to about 3 pounds per cubic foot. Density, cell size and percentage of closed cells can be easily manipulated by those having ordinary skill in the art by appropriate selection of the hydroxyl terminated molecules and isocyanates used to form the rigid urethane foam, and by appropriate selection of blowing agents, cell stabilizers and catalysts. Additionally, the overall sound absorbing/deadening properties of the laminate can be adjusted by varying the thickness of the rigid foam layer 14 and/or varying the density of fibrous batt layer 12. More specifically, higher thicknesses for layer 14 and higher densities for layer 12 will provide generally improved sound absorption/deadening characteristics which are substantially independent of sound frequency.

[0032] The laminated articles of this invention are suitable for use as decorative sound absorbing panels for a variety of automotive applications, including door panels, dashboard panels, console panels, etc., and are particularly well suited for use as vehicle headliners.

[0033] Of course it is understood that the above is merely the preferred embodiment and that changes and alterations can be made without departing from the spirit and broader aspects thereof.

Claims

1. A thermoformable laminate comprising a porous fibrous batt layer and a porous rigid foam layer.

suitable binding resin may be applied before, during or after the fibers are randomly dispersed, to form a suitable fibrous reinforcing mat directly on decorative cover 22. The amount of glass which may be used is as indicated above with respect to the previously described preassembled glass fiber reinforcing mats. Polyester fiber reinforcing mats may be prepared directly on an underlying layer in a similar manner by distributing polyester fibers over the adjacent layer to achieve a weight in the range of about 2.1 ounces per square yard at a thickness of about 12 mils, as described above with respect to the preassembled polyester mat.

[0021] As a further alternative, the reinforcing mat may be comprised of natural fibers or a blend of natural fibers and other fibers, such as glass and/or thermoplastic. Reinforcing mats comprising natural fibers may be prefabricated or prepared directly on an adjacent layer of the laminate, as discussed herein with respect to glass fibers. Preferred natural fibers include sisal, abaca and coconut fibers, with sisal being preferred.

[0022] Decorative cover sheet 22 which covers the front side (the underside or passenger compartment side) of fibrous reinforcing layer 20 is preferably a porous fabric material. A porous fabric will provide minimum interference with the porosity of the end product. A preferred fiber for such fabric would be thermoformable so that cover 22 can be applied to the uncured resin coated surface of reinforcing layer 20 prior to thermoforming. The cured resin then serves as the adhesive to bond cover 22 in place in the final product. A particularly preferred thermoformable polymeric fabric cover sheet comprises a nylon warp knit cloth material.

[0023] Even if a nonporous cover 22 is used, laminate 10 will still provide excellent sound deadening characteristics, i.e., will deaden vibrations of a sound generator. However, porosity is preferred so as not to interfere with the excellent sound absorbing characteristics of porous batt 12.

[0024] Release layer 24 is preferably a porous cloth scrim. Release layer 24 is adhesively secured to fibrous reinforcing mat 16. Release layer 24 prevents sticking of laminate 10 to the thermoforming molding tool surface during the thermoforming operation. After the thermosetable resin has cured in the molding tool, a contoured laminate 20 (shown in FIG. 2) is easily removed from the thermoforming molding tool. The porosity of layer 24 is not critical since it will be on the top side (upper or roof side) of the product in use and sound can still be absorbed through the exposed porous surface of cover 22.

[0025] Rigid foam layer 14 serves two important functions in composite laminate 10. First, the use of a relatively thin rigid foam in combination with a fibrous batt in a composite laminate structure provides significantly enhanced sound absorbing characteristics relative to a laminate of similar thickness, character and structure which does not include a rigid foam layer. Second, the rigid foam layer provides the laminate with improved overall stiffness and/or shape retention properties at relatively high temperatures, whereby the compressed, thermoformed headliner can be removed from the molding tool at a relatively high temperature, as compared with a similar composite article which does not include a rigid foam layer, without sagging or otherwise deforming or losing its shape. For example, a typical thermoforming temperature in the thermoforming molding tool is approximately 130°C. When a laminate of the type generally described herein, but not having a rigid foam layer, is subjected to thermoforming in a thermoforming molding tool to form a porous three-dimensional configuration, the resulting article, and hence the thermoforming molding tool, must be allowed to cool to a temperature of approximately 70 to 75°C before it can be removed from the thermoforming molding tool. By contrast, the rigid foam provides relatively high temperature rigidity and/or shape-retention characteristics which allow the thermoformed article to be removed from the thermoforming molding tool at a much higher temperature. This ability to remove the thermoformed article from the molding tool at a higher temperature results in higher production rates. In particular, the molding tool does not have to be cooled as much after thermoforming, and does not have to be heated as much after a finished article has been removed. Accordingly, the cycle time, (i.e., the time required to form a single three-dimensionally contoured article) can be significantly reduced by utilizing the rigid foam layer 14. Preliminary results indicate that cycle times can be typically reduced by about 30% or more.

[0026] A rigid foam, as used herein, means a thermosetting or thermoplastic foam having low elongation, flexibility and resilience. More specifically, rigid foams refer to foams in which a deformation results in a nonrecoverable change.

[0027] Suitable rigid foams include rigid urethane foam, and other foams exhibiting a similar rigidity or lack of flexibility. Examples of other rigid foam materials which may be suitably employed in layer 14 include other thermosetting foams such as epoxy, isocyanurates, phenolics, silicone and urea formaldehyde foams, and thermoplastic foams such as polystyrene and polyolefin foams. However, rigid polyurethane foams are preferred. The rigid foam layer 14 will preferably have a thickness of from about 2 to 5 millimeters. Thicknesses below 2 millimeters are not preferred because in general, they do not exhibit suitable high temperature shape retention characteristics. Thicknesses greater than about 5 millimeters are not preferred because they add unnecessary and undesirable additional thickness to the finished three-dimensionally contoured laminate article without providing any significant additional benefit beyond those that would be achieved using a thickness of approximately 5 millimeters.

[0028] Rigid foam layer 14 should be sufficiently porous so that one can gently blow air at one side of layer 14 and feel the air coming through the other side.

atively thin, non-extendable, porous mats comprising a plurality of random length, randomly dispersed fibers (or a continuous monofilament strand laid in an overlapping pattern) either thermobonded, i.e., heat-fused, together or bonded together by sufficient binders to bond them (or the bond a single strand upon itself where it overlaps), but not sufficient binder to interfere excessively with porosity. The fibers are primarily oriented in the plane of the mat. Fibrous mats 16, 18 and 20 are sufficiently thin that they do not begin to generate a boardy sound or feel. A thickness of from about 10 to about 20 mils (0.010 to 0.020 inches) is preferred. Suitable glass fiber mats can be obtained, for example, from Gevetex Aachen GmbH of Germany in the monofilament version at 150 grams per square meter or in the staple or plural fiber version at 150 grams per square meter.

[0014] Fibrous mats 16, 18 and 20 are non-extendable in the sense that they will not stretch when exposed to heat in the range of from about 185° to about 250°F, the critical environmental testing temperature for automobile headliners. If mats 16, 18 and 20 were extendable when exposed to such temperatures, headliners formed from such mats would tend to sag when exposed to heat.

[0015] It is also important that fibrous reinforcing mats 16, 18 and 20 be porous to a sufficient degree that they do not act as sound reflectors in the same sense as a sheet of kraft paper, a polymer film or a layer of rigid glass fiber reinforced resin. The porosity of mats 16, 18 and 20 allow sound to penetrate and be absorbed by the non-woven fiber batt 12 rather than bounce off mats 16, 18 and 20. While precise measures of porosity are difficult to specify and while there will be a great deal of latitude allowed to those skilled in the art, mats 16, 18 and 20 are preferably sufficiently porous that one can gently blow air at them and feel the air coming through the other side. Typically, mats 16, 18 and 20 will have a light porosity or void spaces in the range from 60 to 80%, preferably 70%, determined by the percentage of light passing through the mat. Air porosity for such mats will be an access of 90%, e.g., 98%.

[0016] Fibrous reinforcing mats 16, 18 and 20 are formed from fibers having a softening temperature which is greater than that of the fibers comprising fibrous batt 12. Preferably the fibers used in reinforcing mats 16,18 and 20 will not soften at temperatures below 350°F, more preferably fibers which will not soften at temperatures below 400°F, and most preferably fibers which will not soften at temperatures below 500°F. High melting points polyester fibers are acceptable, i.e., fibers having a softening temperature at temperatures above about 400°F. Glass fibers are most preferred, especially glass fibers having a softening temperature in access of 500°F.

[0017] In accordance with a preferred mode, fibrous reinforcing mats 16, 18 and 20 may comprise a plurality of glass fibers bonded together by a resin. The mats are preferably from about 10 to 20 mils thick. The glass fibers are chopped from roving in which the individual fibers are approximately 10 microns thick. The fibers typically have a specific gravity of about 2.5 to 2.7. The weight of the glass in the glass fibrous reinforcing mats 16, 18 and 20 is preferably from about 80 to 150 grams per square meter.

[0018] The amount of resin binder used to adhere fibrous reinforcing mats 16, 18 and 20 to the adjacent layers 12, 14, 22 and 24 as shown in FIG. 1, is preferably from about 15 grams per square meter to about 45 grams per square meter, e.g., 30 grams per square meter, although higher amounts may be used, provided that the binder does not interfere excessively with porosity, and lower amounts may be used provided that sufficient adherence between the layers is achieved. Suitable binding resins include heat curable thermosetable resins which may be applied in liquid form, and which remain liquid until heated in a thermoforming molding tool. Examples of suitable thermosetable resins include phenolic resin, urethane resin and melamine resin, with urethane resin being preferred. An example of a suitable thermosetting resin is an elastomeric urethane composition comprising 100 parts by weight of a polyol having three or four hydroxyl groups, 85 parts by weight of an isocyanate compound having at least 2 reactive isocyanate groups, such as methylene-bis(phenyl isocyanate), 0.05 to 0.10 parts of a catalyst such as tin octoate or lead naphthanate, and 5 to 20 parts of solvent such as trichlorofluoromethane or methylene chloride. The solvent serves to dilute the solution in order to facilitate its application by spraying, brushing or by an impregnating roller. An example of a commercially available elastomeric urethan resin is Butofan™ Ds 2165, available from BASF GmbH.

[0019] An alternative mat material which may work in some circumstances, but which is not as effective as the above described porous fiberglass mat is a spunbonded polyester mat of comparable porosity and thickness. A high temperature polyester fiber must be employed. A example of such material is a 2.1 Bontex™ available from Van Waters & Rogers, Inc. of Kansas City, Kansas. This material weighs in the range of 2.1 ounces per square yard at a thickness of about 20 mils, or about 15 pounds per cubic foot. The individual fiber density is about 1.38 grams per cubic centimeters. The fibers have a softening temperature in excess of 400°C. This material is somewhat less porous, given that the overall mat densities are comparable and the fiber density per se is less. Nevertheless, one can notice the passage of air through the mat when blowing air against it.

[0020] As another alternative, to using either a prefabricated glass fiber mat, or a prefabricated polyester fiber mat, the reinforcing layers 16, 18 and 20 may be prepared directly on top of an underlying adjacent layer, either before the underlying layer is placed in the thermoforming mold, or after. For example, chopped glass fibers of random length can be randomly dispersed over the back side (top side) of decorative cover 22, and a

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

FIG. 1 schematically illustrates a cross-sectional view of a laminated structure formed in accordance with the invention with the laminate layers shown separated for convenient illustration; and

FIG. 2 shows the same structure after molding, again with the laminate layers shown separated for convenient illustration.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] In the preferred embodiments, laminate 10 includes a resilient, porous fibrous batt layer 12 and a rigid foam layer 14. Bonded to each side of the porous fibrous batt 12 is a porous reinforcing mat, 16 and 18, respectively. Bonding of the fibrous, porous reinforcing mats 16, 18 to the opposite sides of the porous fibrous batt may be achieved by applying a binding resin to reinforcing mats 16, 18 and/or the opposite surfaces of fibrous batt 12, preferably shortly before the laminate is thermoformed in a thermoforming molding tool. The expression "thermoformed" as used herein refers to a process whereby a laminate is shaped in a molding tool under the influence of heat and pressure. Rigid foam layer 14 is likewise bonded to reinforcing mat 18 on the side opposite the side bonded to fibrous batt 12. Preferably, prior to thermoforming of the laminate, an additional fibrous, porous reinforcing mat 20 is bonded to rigid foam layer 14, on the side thereof opposite the side bonded to fibrous, porous reinforcing mat 18, and a decorative fabric cover 22 is bonded to the side of fibrous, porous reinforcing mat 20 opposite the side bonded to rigid foam 14, and fibrous reinforcing mat 16 is covered by a mold release liner 24. Laminate 10 is moldable to form a predetermined geometrical configuration, typically exhibiting a three-dimensional shape having contoured surfaces characterized by the presence of one or more compound curves (see FIG. 2).

[0010] Resilient, non-woven fibrous batt 12 comprises a multitude of directionally or substantially randomly oriented synthetic or natural fibers having a denier of about 4.5 to about 25. Fibrous batt 12 is formed from fibers having a length of from about ½ inch to about 3 inches. Fibrous batt 12 has a thickness of about 15 to 30 millimeters, and more preferably from about 20 to about 25 millimeters prior to being compressed in the thermoforming operation. The weight of fibrous batt 12 is from about 200 to about 400 grams per square meter. Fibrous batt 12 of the preferred embodiment is comprised of oriented fibers, wherein a portion of the fibers are preferentially oriented, such as transverse to the planes of the surfaces of the batt. For example, fibrous batt 12 may be needled to cause the fibers to intermesh and to cause a portion of the fibers to orient generally transversely to the planes of the surfaces of the batt. When a substantial portion of the fibers are oriented generally transversed to the planes of the surfaces of the batt, the ban has improved resilience. Resilience and porosity of non-woven batt 12 may be desirable in certain situations and may provide improved sound absorbing/deadening characteristics in certain cases.

[0011] The fibers used to form fibrous batt 12 are preferentially thermoformable. It is desirable that the fibers take a set when placed in a heated mold so that they will tend to hold a three-dimensional configuration. Also, it is desirable that the fibers be compressible in a heated thermoforming molding tool so that tight, compact margins can be formed at the edges of the thermoformed article or at edges of openings therein. Fibrous batt 12 may be comprised of synthetic fibers, natural fibers, or a combination thereof. Suitable natural fibers include plant fibers such as cotton. However, thermoplastic fibers are preferred. Suitable thermoplastic fibers include polyester fibers, polyolefin fibers such as polypropylene and polyethylene, and polyamide fibers such as nylon. The selected thermoplastic fibers should have a melting point which is substantially greater than the temperatures to which the end products may be exposed during its intended use. However, the melting point of the thermoplastic fibers should be low enough that the fibrous batt will take a set and compact at the edges at a reasonable thermoforming temperature, e.g., 250°F to 350°F. Non-woven polyester fibers, particularly polyethylene terephthalate (PET) are preferred in forming the non-woven fibrous batt 12 of this invention because of their excellent elongation and molding characteristics at molding temperatures.

[0012] The fibers comprising porous fibrous batt 12 are preferably either thermobonded, i.e., heat-fused, together, or bound together by sufficient binder to bond the fibers together at points of intersection thereof, but not sufficient binder to interfere excessively with porosity. When fibrous batt 12 is comprised of thermoplastic fibers, the fibers are preferably heat-fused together at their points of intersection. Bi-component fibers comprising a core polymer having a relatively high glass transition temperature, and a sheath polymer having a relatively lower glass transition temperature may be advantageously employed in the fibrous batts 12 of this invention. When a blend of synthetic and natural fibers are used, the synthetic fibers are preferably thermoplastic fibers which are heat-fused to each other and to the natural fibers at points of intersection between the fibers. In certain cases, especially where fibrous batt 12 is comprised primaily or entirely of natural fibers, it will be desirable to bond the fibers to one another at points of intersection between the fibers using a thermoplastic binder resin. Examples of suitable binding resins include water dispersed acrylic, ethylene vinyl acetate acrylic, styrene butadiane rubber, polyvinyl acetate and polyvinyl acrylic copolymer.

[0013] Fibrous reinforcing mats 16, 18 and 20 are rel-

Description

BACKGROUND OF THE INVENTION

[0001] This invention relates to vehicle headliners and a method of forming vehicle headliners, and more particularly to vehicle headliners comprising a plurality of thermoformable layers which are compressed and molded to form a laminate having a predetermined contoured shape.

[0002] Many vehicle headliners have been constructed utilizing resin impregnated glass fiber. A resin impregnated glass fiber batt is compression molded into the desired headliner shape, and the resin is cured to maintain the molded shape. A thin layer of foam, such as polyurethane, overlies the molded fiberglass shape, and fabric is attached to the foam to form the exposed interior surface of the headliner. Because the glass fiber reinforced layer of such headliners is a rigid, often impermeable layer, it tends to reflect sound. Accordingly, undesirable ambient noises, including noise from the engine compartment or drive train, which enter the cabin are not absorbed by the headliner, but instead are reflected back into the cabin by the fiber reinforced resin layer.

[0003] Another type of vehicle headliner is prepared by thermoforming a laminate comprised of a stiff structural, yet thermoformable polystyrene foam layer and layers of kraft paper or a polymer film material bonded to either side of the foam. This laminate is covered with a soft foam backed fabric. Such headliners do not have sufficiently desirable sound absorbing properties because the kraft paper or polymer film tends to reflect sound rather than absorb sound.

[0004] A sound absorbing laminate which is useful for forming three-dimensionally contoured articles such as automobile headliners, and which exhibits substantially improved sound absorbing properties, is disclosed in U.S. Patent No. 5,068,001, the rights of which have been assigned to Prince Corporation, Holland, Michigan, the Assignee of the present invention. The laminate is comprised of a resilient, porous fibrous core layer, to which is adhered a fibrous, porous reinforcing mat to give the composite strength. The three-dimensional sound absorbing structure is generally formed by providing a first reinforcing porous, fibrous mat, providing a core defined by a resilient thermoformable porous fiber batt having a thickness of at least about ¼ inch, laminating the mat to one surface of the batt by impregnating the mat and its interface with the batt with sufficient binder resin to effect adherent therebetween, but insufficient resin binder to form a porosity-blocking film, and thermoforming the laminate into a porous three-dimensional configuration. While the sound absorbing laminate described in U.S. Patent No. 5,068,001 provides substantially improved sound absorbing properties as compared with other known vehicle headliner constructions, vehicle manufacturers desire even better sound absorbing properties, and in particular desire headliner constructions which are capable of exhibiting excellent sound absorbing properties for particular frequency ranges depending on the characteristics of the vehicle. Also, while the method described in U.S. Patent No. 5,068,001 is useful for mass producing automobile headliners on automated equipment, the amount of time which the laminate must remain in either a thermoforming molding tool or placed in a cooling fixture having a shape substantially identical with that of the molding tool, in order to form a high quality headliner in the desired three-dimensionally contoured configuration, can be more than is desirable.

SUMMARY OF THE INVENTION

[0005] In the present invention, it has been surprisingly found that substantially improved sound absorbing characteristics can be achieved, and that enhanced sound absorbing properties for a particular selected range of sound frequencies can be achieved using a laminate comprising a porous fibrous layer and a porous rigid foam layer. The combination of a porous fibrous layer and a rigid foam layer has been found to provide improved sound absorbing characteristics over substantially the entire range of sound frequencies which can be detected by the human ear. Additionally, the inventors have found that by varying the thickness of the layers and by varying the porosity and density of the rigid foam layer, the headliner can be tuned to exhibit specially enhanced sound absorbing properties for a particularly selected range of frequencies.

[0006] In addition to achieving improved sound absorbing characteristics, the three-dimensionally contoured panels of the invention can be mass produced at higher production rates, and therefore at a lower cost. More specifically, it has been found that the rigid foam layer helps retain the desired three-dimensionally contoured shape at a higher temperature, whereby the thermoformed three-dimensionally contoured panel can be removed from the thermoforming molding tool at a higher temperature. As a result, shorter cycling times are required and more three-dimensionally configured panels can be produced per unit time for a given thermoforming molding tool.

[0007] Another advantage with the present invention is that the laminate comprising a porous fibrous core layer and a rigid foam layer can be thermoformed using the same thermoforming molding tools which are used for producing the three-dimensionally contoured panels described in U.S. Patent No. 5,068,001. These and other objects, advantages and features of the present invention will be more fully understood and appreciated by reference to the written specification and appended drawings.

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(54) Acoustical composite headliner

(57) A thermoformed contoured three-dimensional laminated structure (10) having improved sound absorbing characteristics and which can be formed with shorter mold cycle times includes a porous thermoformable fibrous batt layer (12) and a rigid foam layer (14). The laminated articles are suitable for use as decorative sound absorbing panels for automotive applications, and are well suited for use as vehicle headliners.

EP 0 949 066 A2

fiber; and
curing said applied adhesive and said agricultural fiber to form a sheet;

providing a foam layer;
partially saturating said foam layer with a liquid adhesive;
placing one said sheet of agricultural fiber on each side of said foam layer;
placing a decorative material on one of said sheets of agricultural fiber;
placing a backing on the other of said sheets of agricultural fiber; and
squeezing together said foam layer, said sheets of agricultural fiber, said decorative material, and said backing to form a laminated sheet.

12. The method of making a headliner according to claim 11, wherein said partially saturating step comprises drawing said foam layer into a bath of said liquid adhesive prior to placing said foam layer between said sheets.

13. The method of making a headliner according to claim 11, wherein said distribution step includes the step of separating said fibers to minimize agglomeration.

14. The method of making a headliner according to any one of claims 11 to 13, wherein said distribution step includes the step of vibrating said fibers to maintain a uniform distribution of said fibers.

15. The method of making a headliner according to any one of claims 11 to 13, wherein said step of applying an adhesive to said agricultural fibers comprises spraying an adhesive on said agricultural fibers.

16. The method of making a headliner according to any one of claims 11 to 15, wherein said step of placing a decorative material on one of said sheets of agricultural fiber includes the steps of providing a fabric and a foam resin layer and joining said fabric and said foam resin layer.

17. The method of making a headliner according to any one of claims 11 to 16, further comprising at least one of the following steps:

(a) placing an adhesive sheet between said one of said sheets of agricultural fiber and said decorative material;
(b) molding said laminated sheet; and
(c) severing said laminated sheet to shape.

0.7-2 pounds per cubic foot; the foam should have an ILD in the range 10-80; and a permeability based on Dow Chemical Flow Meter in the range 2-8 cfm, preferably 4-6 cfm. Where this foam is used with the prior art isocyanate resin and amine catalyst the cured resin makes the foam layer too crumbly or brittle for effective use; blemishes at the decorative surface are too evident. On the other hand, where the polyurethane liquid resins (VORANOL 446 and 800) are used, the cured resin and foam combination is sufficiently rigid for parts like headliners yet flexible enough to bend without breaking. The combined flexibility and rigidity is critical in the installation process.

The theory of operation for the headliner is that the two layers of agriculture fiber 30 act as the outside flanges of an I-beam and the foam layer 36 is the bridge between the flanges. The combination of the foam and cured polyurethane resin achieves a desired compression modulus to allow the fiber layers to perform their I-beam functions. Should the bending forces on the headliner overcome the compression modulus, the cured polyurethane is sufficiently flexible as to allow the foam to partially collapse. The agricultural fiber layers 30 remain the same length and the crinkling of inner layer 30 is allowed because of the properties of foam core 36. This allows a resilient flexing of all the layers without a cracking or breaking of the laminate. Thus, there is no blemish to propagate to the decorative surface. To facilitate a uniform controlled crimp or crinkle pattern where a fold is expected, surface grooves may be formed in the laminate by the molds. Thereby, when the molding step takes place as illustrated in US-A-5 468 256 a turkeyfoot pattern is predictable as to pattern and location.

One significant advantage of substituting liquid polyurethane 39 for isocyanate is the reduction of curing temperature. Isocyanate cures at about 375°F. At that high temperature it is not possible to use a vinyl decorative layer in the single molding step of this invention. Vinyl deteriorates at 375°F. The liquid polyurethane of this invention cures at about 250°F.

Having thus described the invention in its preferred embodiment, it will be clear that other modifications may be made without departing from the spirit of the Invention. Also the language used to describe the inventive concept and the drawings accompanying the application to illustrate the same are not intended to be limiting on the invention. Rather it is intended that the invention be limited only by the scope of the appended claims.

Claims

1. A headliner formed from laminated layers of polyurethane foam, agricultural fibers, a decorative material, and a backing, wherein,

   a layer of agricultural fiber is secured on each side of said foam, said layer of agricultural fiber being a sheet having a weight less than 25 grams per square foot and including an adhesive, each layer of agricultural fiber being bonded to said foam by a liquid adhesive partially saturating said foam and in contact with said sheet of agricultural fiber;

   said decorative material is attached to one said sheet of agricultural fiber by an adhesive sheet; and

   said backing is attached to one said sheet of agricultural fiber.

2. The headliner according to claim 1, wherein said agricultural fiber is selected from the group consisting of jute, sisal, kenaf and mixtures thereof.

3. The headliner according to claim 1, wherein said agricultural fiber has a weight between about 5 grams per square foot and about 8 grams per square foot.

4. The headliner according to claim 2, wherein said agricultural fiber has a weight between about 7 grams per square foot and about 7 1/2 grams per square foot.

5. The headliner according to claim 1, wherein said adhesive in said sheet of agricultural fiber is a latex adhesive.

6. The headliner according to claim 1, wherein said agricultural fibers are chopped to have a length between about 1 and about 4 inches.

7. The headliner according to claim 6, wherein said agricultural fibers are chopped to have a length between about 1 1/2 inches and about 3 inches.

8. The headliner according to claim 1, wherein said decorative material comprises a fabric attached to a foam resin.

9. The headliner according to claim 1, wherein said adhesive sheet comprises an ethylene acrylic acid copolymer.

10. The headliner according to claim 1, wherein said liquid adhesive is a thermosetting adhesive.

11. A method of making a headliner, comprising:

    forming sheets of agricultural fiber, comprising:

    providing an agricultural fiber;
    chopping said agricultural fiber to provide individual fibers of specified length;
    distributing said agricultural fiber on a surface;
    applying an adhesive to said agricultural

Fig. 3.

By way of illustration only, a small roller 40 forces the foam layer 36 into the urethane resin 39 to partially saturate the same ad its purpose will be explained subsequently.

A layer of decorative fabric 42 is drawn from roll 44 and is directed to the conveyor belt 34 in over lying condition above one of the layers of fiber sheet 30 and foam layer 36 by a small roller or guide 46.

The roll of decorative material 44 is supplied as a composite of a fabric 48 suitable for an exposed surface of the headliner inside the passenger compartment of a vehicle. Fabric 48 is flame bonded or laminated to a thin polyurethane foam resin layer 50. Note that this disclosed layering sequence is illustrated in Fig. 3, but the flame lamination of the foam layer 50 to the decorative fabric 48 is done elsewhere and the roll 44 supplied as a laminated source material as a composite unit.

A sheet of adhesive 52 is supplied from a roll 54 and is delivered to conveyor belt 34 by guide 46 such that the adhesive sheet 52 is located between the saturated polyurethane foam layer 36 and thin foam resin layer 50.

Adhesive sheet 52 may be ethylene acrylic acid copolymer sold under the trade designation of Dow Chemical Company as Dow 899 or a laminated structure designated Dow 906 which comprises an impermeable polyethylene sheet having layers of the aforesaid copolymer at each surface. The impermeable polyethylene layer may be used where it is desirable that a liquid impermeable barrier be established between the decorative fabric 48 and the liquid impregnated foam layer 36. Note that sheet 30 is not impermeable.

The bottom layer as illustrated in Fig. 2 is preferably a polyester fibrous backing 56 supplied from a roll 58 and it may serve as a good bonding surface for VELCRO patches or the like to hold a molded headliner in place inside the passenger compartment of a vehicle.

After the layered structure is oriented on conveyor belt 34 it is directed between a rubber roller 60 and a steel roller 62. Rollers 60 and 62 squeeze the composite so that the liquid polyurethane resin impregnating layer 36 is squeezed into contact with the agricultural fiber layers 30 to bond all of the layers together. The porous structure of layers 30 allows the liquid polyurethane 39 to penetrate to juxtaposed layers 52 and 56.

As indicated earlier where there is some concern that the liquid resin in layer 36 may propagate to the surface of fabric layer 48 and create unsightly stains, the layered adhesive sheet 52 comprised of the Dow 906 product is used.

After departing from the pinch rollers 60, 62 the conveyor belt 34 delivers the laminated sheet 64 to a roll 66 where it is stored for subsequent use if desired. It may be that the composite layer 64 will be delivered directly to the molding system and severed to shape immediately after leaving the conveyor belt 34. The system for forming the laminate of Fig. 3 into the desired shape is described in the aforementioned US-A-5 468 256 and need not be repeated here.

The thermosetting adhesive resin mixture 39 applied at 40 is about 36-50% polyether polyol by weight, preferably in the range of about 40-60% by volume, about 50-64% aromatic isocyanate by volume with an appropriate catalyst if desired of about 0.0 - 0.2% by volume. Preferably the volume of isocyaate is in the range from about 52-63%. The resin mixture 39 should have a ratio of isocyanate equivalents to polyol equivalents index above about 1-1.65.

Preferred polyols comprise a hydroxyl terminated poly(oxyalkylene) polyol, most preferably a hydroxyl terminated poly(oxyethylene) polyol of appropriate molecular weight and functionality, such as obtainable from Dow Chemical as VORANOL 446. A small amount of (up to about 6%) VORANOL 800 (trademark of Dow Chemical Co.) may be used effectively. Such polyether polyols may be used in the adhesive mixture 39 to achieve the desired hardness and flexibility in the cured resin.

The preferred isocyanate is a polymethylenepolypheylene ester of isocyanate acid, such as obtainable from Mobay Corporation under the trade designation MONDUR MR or Dow Chemical designation Dow Pappi 2027, whose composition consists essentially of about 45 - 55% of diphenylmethane diisocyanate (MDI), about 45 - 55% of higher oligomers of MDI, and a trace of phenyl isocyanate.

Suitable catalysts are available from Air Products and Chemicals, Inc. under the trade designation DABCO T-12 (a specially formulated high-boiling liquid dibutyltin dilaurate) or the like. The proportions of catalyst needed may vary, depending upon curing temperature, relative humidity of the air (normally in the rage 35-80%) and other factors known in the industry. By way of preferred example, in the above stated environmental conditions, about 0.11 parts per 100 parts polyol. Preferably the catalysts are added to the polyol prior to its mixture with the isocyanate. With adequate increased portions of the VORANOL 800 resin, the catalyst may be eliminated entirely.

While the preferred embodiment is described with a particular polyol, isocyanate and catalyst, it will be clear that the time periods and the temperatures for curing could be modified by adjustment of the catalyst and other parameters and these would be obvious modifications well within the inventive concept. Similarly, the curing time might be reduced for the liquid resin adhesive by a controlled increase in the humidity in the vicinity of the mold.

The preferred foam for foam layer 36 is sold under the trade designation Carpenter L51Y (density 1.2, 65 ILD). A useful foam is Burkart 12024 (density 1.2, 24 ILD). Preferably foam layer 36 has a thickness of about 0.1-1.1 inches and most preferably a thickness of about 1/4 inch. The density has an operable range of about

said liquid resin being squeezed from said foam layer into the adjoining fiber glass layers,

(i) applying a cover layer over said second layer of fiber glass, said cover layer being selected from the group consisting of a woven fabric, a permeable vinyl sheet, and an impermeable vinyl sheet,

(j) placing said laminate and cover layer between a pair of molds for a period of about 1/2-3 min. and at a temperature in the range of about 230°-375°F. to form a preform to a desired shape, and

(k) severing the peripheral edges of said preform to a desired configuration.

The use of fiber glass is a problem as indicated above.

The headliner of this invention substitutes a layer of agricultural fibers for the layers of fiber glass in the Romesberg et al. patent. Therein lies the difficulty.

The composite laminated structure to form the headliner or other useful panel requires a relatively uniform distribution of fibers laminated to the thick or central foamed resin layer. The problem is that glass is easily delivered in strands or bundles which may be severed or chopped easily to a uniform size. Glass fibers easily fall for easy distribution of uniform density on a conveyor belt or other impervious layer below. Glass fibers may be chopped to size easily and when they fall they do not agglomerate. That is the distinction from agricultural fibers.

When used in this specification the terms "agricultural fibers" is intended to mean jute, sisal, kenaf or their equivalent.

Distribution of the agricultural fibers in layers having a weight of about 7 grams/ft^2 both above and below a central polyurethane foam layer comprises the greater thickness of the panel being formed is the preferred layering sequence.

To the extent necessary for an understanding of this invention, US-A-5 468 256 is incorporated herein by reference.

Objects of the invention not understood from the above will be fully appreciated upon a review of the appended drawings and the description of the preferred embodiment which follow.

Fig. 1 is a schematic illustration of the formation of a sheet of agricultural fibers wound and stored on a roll for subsequent use;

Fig. 2 is a schematic representation of the formation of a laminated panel according to this invention before it is formed into a headliner, door panel or the like; and

Fig. 3 is a fragmentary sectional view showing the laminated layers of the panel of this invention.

Looking to Fig. 1, a supply of natural agricultural fiber 10 is cut to length and distributed at 12 to a vibrator 14.

Prior to delivering fibers through feed line 12, the fibers are chopped to a suitable size. In the preferred embodiment herein the fibers are chopped to have a length between 1 and 4 inches and more preferably between 1 1/2 and 3 inches.

The vibrator 14 is to keep the mat of fibers in a somewhat fluid state as it progresses to a separator or fiber opener 16. Separator 16 is shown as a block and there may be various ways for keeping the agricultural fibers from agglomerating prior to their distribution on a conveyor belt which will be explained subsequently. Ways of separating fibers so they may be delivered with some sort of uniform delivery system across a cross-sectional area are known. Some include toothed rotating drums to fling the fibers in all directions inside a housing and keep it supported on an air bed or the like. There are undoubtedly dozens of others ways of doing this and one would certainly be an ionization process which might be incorporated to cause the various fibers to have a repelling charge distributed thereon. In any case, the separated fibers are discharged by a material handling fan, nozzle or other suitable structure at 18 onto a moving conveyor belt 20. The fibers 22 are required to be delivered onto the conveyor belt to have a distribution of less than 25 grams per square foot, preferably about 5-8 grams of fibers per square foot of surface area and most preferably about 7 - 7 1/2 grams/ft^2. Preferably the conveyor belt 20 is about 72 inches wide. Clearly the fibers 22 may be distributed manually if necessary.

Immediately down stream of the discharge outlet 18 is a nozzle 24 which sprays an adhesive 26 from a storage container 28. Preferably the adhesive is a latex adhesive similar to ELMER'S (Registered Trade Mark) glue purchased from Evan's Adhesives in Columbus, Ohio, United States of America, Adhesive No. 8186.

As the conveyor belt 20 progresses beyond the adhesive nozzle 24, the adhesive cures to freeze the fibers in place such that a thin flexible sheet 30 is formed and rolled on roller 32 for further use. The portion of adhesive 26 in layer 30 is relatively small such that it holds the fibers 22 in relative position but the layer is porous for easy passage of air or liquids as discussed subsequently.

Looking now to Fig. 2, two rolls 32 of the sheets of fibers are mounted adjacent a second conveyor belt 34. It will be clear that the showing is a schematic illustration rather than a detailed dimensionally correct working engineering drawing.

A roll 34 of a sheet 36 of polyurethane foam is drawn to a bath 38 of liquid polyurethane adhesive 39 and subsequently is directed to the conveyor belt 34 to be sandwiched between the two layers of fiber sheet 30, one sheet of agricultural fiber 30 being on one side 43 of said foam layer 36 and one sheet of agricultural fiber 30 being on the other side 45 of said foam layer 36, see

Description

This invention relates to a laminated panel and one use contemplated for the panel is as a headliner in the passenger compartment of trucks and passenger vehicles.

Headliners for vehicles are conventionally constructed of fiber glass or multi-layered laminated panels incorporating fiber glass and foam resin layers. In the conventional manufacturing process, the layers are placed between mirror image mold surfaces, compressed, heated to cure an incorporated thermosetting resin, and then cut to shape at their periphery. Sometimes apertures for window openings, light fixtures, sun visors and the like are cut in the panels after molding. More often than not, in the assembly of the vehicle the headliner is inserted through the front window before the windshield is mounted. The typical headliner is in the shape of a dome with the concave surface facing downward. It is sufficiently rigid to hold its shape when mounted in the passenger compartment and supported along its side edges with the central part of the headliner juxtaposed to the roof.

Various problems exist in the assembly of the headliner and one of those problems is that the headliner includes a decorative layer as the exposed surface visible to the passengers. Any folds, creases or blemishes in the visible surface creates a problem for one marketing the vehicle. As a practical matter, it is unacceptable to have exposed blemishes. Also, breakage is a problem due to brittleness of the cured structure.

The headliner serves three other functions in addition to aesthetics which may be at odds with the concern for exposed blemishes. One function is to provide a soft surface to minimize injury with head bumps. Fiber glass headliners are hard as are conventional headliners incorporating foamed resin and do not provide much padding for one's head. The only cushioning is in the decorative fabric which may or may not have a soft foam backing. A second function is to provide insulation from heat between the roof of the vehicle and the interior or passenger compartment. The third function is to provide sound insulation from exterior wind noise, engine noise, and the like.

A common solution to the problem of heat and noise insulation is to use foamed resin layers in the headliner. The foamed resin is a better heat and sound barrier than resin impregnated fiber glass. Unfortunately, the foamed resin most often used is of the "closed cell" variety which includes a plurality of bubbles throughout the resin. Such foamed resin is initially quite rigid and with a sealed skin coating it is even more rigid. Therefore, when the headliner must be bent or folded out of its original molded shape to get it into the proper position for installation in the vehicle it often cracks and/or ruptures bubbles within the foamed layer itself. This often leaves a crease in the headliner which is visible through the fabric. That is also true of fiber glass headliners. Exposed creases are a problem because a exposed crease makes the flawed headliner unusable from a practical standpoint. As a consequence of the problem, the size of the windshield opening is often dictated by the size of the headliner which must be inserted (whether the vehicle manufacturer knows it or not). Making the windshield opening larger minimizes deflections of the headliner to get it in operative position.

The problem with fiber glass in headliners, wall panels, etc., is an environmental one. Glass fibers are not recyclable and when a waste or old product is discarded it is not biodegradable ad cannot be burned.

Attention is directed to Romesberg et al., US-A-5 468 256, the disclosure of which is essentially set out in its claim one:

> 1. A process for making a flexible laminated sheet of foamed resin and fiber comprising,
>
> (a) providing layers of open celled polyurethane foam and non-woven scrim, said foam having a thickness in the ranges of about 0.1 to 1.1 inches, and ILD in the range of 10-80, a density in the range of 0.7-2 pounds per ft^3, and a permeability in the range 2-8 cfm,
> (b) providing a layer of material over said scrim layer,
> (c) chopping strands of fiber glass to a length in the range 1.5-3 inches and depositing by gravity a first layer of fiber glass over said layer of material, said fiber glass being applied in a density in the range 4-16 gm/ft^2, said layer of material between said first fiber glass layer and said scrim layer confining and supporting said first fiber glass layer.
> (d) impregnating said layer of foam with a liquid polyurethane resin, said liquid resin comprising a mixture of about 40-50 volume percent aromatic isocyanate, about 50-60 volume percent polyether polyol, and about 0.0-0.2 volume percent of a catalyst,
> (e) running said impregnated foam layer between a first pair of rollers to provide a uniform non-saturating dispersion of said liquid resin in said foam layer,
> (f) depositing a second layer of fiber glass over said foam layer, said second fiber glass layer having similar physical characteristics as said first fiber glass layer and being chopped and deposited on said foam layer in the same way as said first fiber glass layer is deposited on said layer of material,
> (g) applying said impregnated foam layer ad second fiber glass layer over said first fiber glass layer with the foam layer sandwiched between said two fiber glass layers,
> (h) compressing all layers together between a pair of calendar rollers to form a laminate with

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(54) Headliner and method of manufacturing

(57) A headliner is a laminate of multiple layers. The layers include polyurethane foam (36,50), agricultural fibers (30), a decorative material (48), and a backing (56). The agricultural fiber (30) is jute, sisal, or kenaf or mixtures thereof. The method of making the headliner laminate includes making the sheet of agricultural fibers incorporating a binder, saturating a foam layer with an adhesive, putting one sheet of agricultural fibers on each side of the foam layer, applying the decorative material and backing to one side each, and squeezing the layers together to distribute the adhesive to all the layers and laminate them.

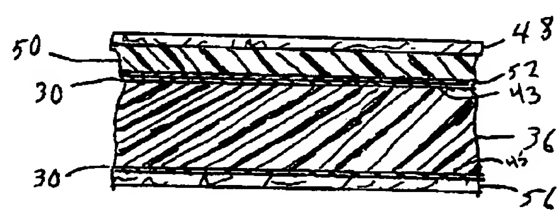

Fig. 3

EP 0 832 787 A1

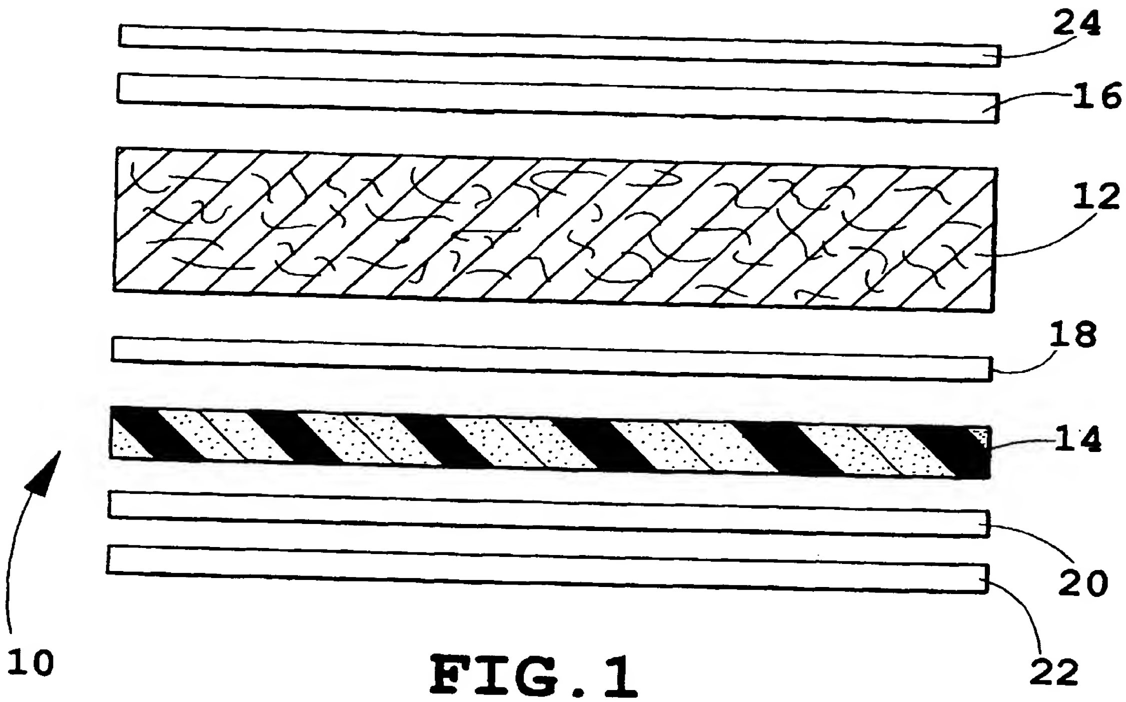

FIG. 1

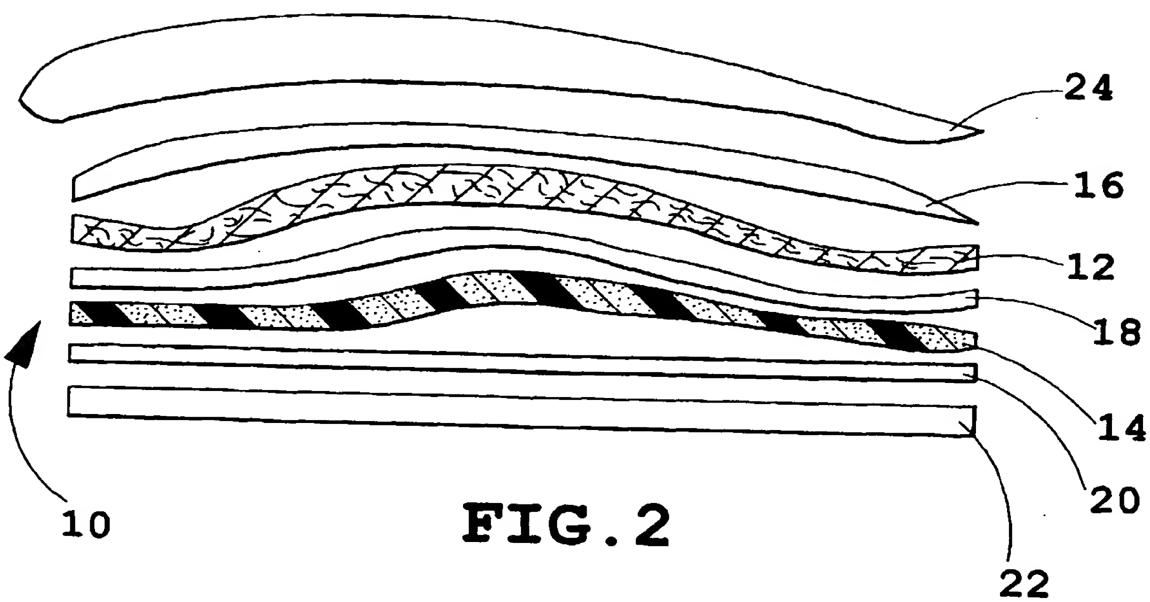

FIG. 2

about ½ inch to about 3 inches and a denier of about 4.5 to about 25, and wherein the fibrous batt has a weight of from about 200 to 400 grams per square meter.

25. The method of claim 24, wherein the reinforcing layer has a thickness of from about 10 to about 20 mils and a weight of from about 80 to about 150 grams per square meter.

26. The method of claim 23, wherein the thickness of the rigid foam layer is from about 2 to about 5 millimeters.

27. The method of claim 21, wherein the layers are theremoformed into a vehicle headliner.

28. The method of claim 21, wherein the reinforcing layer comprises natural fibers.

29. The method of claim 21, wherein the reinforcing layer comprises sisal fibers, abaca fibers, coconut fibers or a combination thereof.

2. A molded contoured three-dimensional laminate comprising a porous fibrous batt layer and a porous rigid foam layer.

3. A laminate according to either of claims 1 or 2 further comprising a reinforcing layer disposed between the fibrous batt layer and the rigid foam layer, the reinforcing layer comprising fibers having a softening temperature greater than fibers of which the fibrous batt is comprised.

4. The laminate of claim 3 when dependent on claim 1, wherein a thermosettable resin is disposed at interfacing surfaces between the fibrous batt layer and the reinforcing layer, and between the reinforcing layer and the rigid foam layer.

5. The laminate of claim 1, wherein the fibrous batt layer is comprised of natural fibers, synthetic fibers, or a blend thereof.

6. The laminate of claim 3 when dependent on claim 2, wherein the reinforcing layer is adhered to the fibrous batt layer and to the rigid foam layer by a thermoset resin.

7. The laminate of claim 1 or claim 6, wherein the fibrous batt layer is comprised of thermoplastic fibers.

8. The laminate of claim 7 when dependent on claim 6, wherein the thermoplastic fibers are polyester fibers.

9. The laminate of claim 8, wherein the polyester fibers are polyethylene terephthalate fibers.

10. The laminate of claim 1, wherein the fibrous batt layer is comprised of polyester fibers.

11. The laminate of claim 1, wherein the fibrous batt is comprised of polyethylene terephthalate fibers.

12. The laminate of claim 3 when dependent on claim 1 or claim 9 when dependent on claim 8, wherein the reinforcing layer comprises glass fibers.

13. The laminate of claim 4 or claim 12 when dependent on claim 9, wherein the thermosettable resin is selected from phenolic, urethane and melamine resins.

14. The laminate of claim 1 or claim 13 when dependent on claim 12, wherein the rigid foam layer comprises a rigid polyurethane foam.

15. The laminate of claim 1 or claim 14 when dependent on claim 13, wherein the fibrous batt layer is comprises of fibers having a length of from about ½ inch to about 3 inches and a denier of about 4.5 to about 25, and wherein the fibrous batt layer has a thickness of from about 15 to about 30 millimeters and a weight of from about 200 to 400 grams per square meter.

16. The laminate of claim 3 when dependent on claim 1 or claim 15 when dependent on claim 14, wherein the reinforcing layer has a thickness of from about 10 to about 20 mils and a weight of from about 80 to about 150 grams per square meter.

17. The laminate of claim 3 when dependent on claim 1 or claim 16 when dependent on claim 15, wherein the thickness of the rigid foam layer is from about 2 to about 5 millimeters.

18. The laminate of claim 17 when dependent on claim 16, configured as a vehicle headliner.

19. The laminate of claim 3 when dependent on claim 1, wherein the reinforcing layer comprises natural fibers.

20. The laminate of claim 3 when dependent on claim 1, wherein the reinforcing layer comprises sisal fibers, abaca fibers, coconut fibers or a combination thereof.

21. A method of forming a molded contoured three-dimensional laminated structure comprising:

providing a porous, thermoformable fibrous batt layer;
providing a porous rigid foam layer;
disposing a reinforcing layer between the fibrous batt layer and the rigid foam layer, the reinforcing layer comprising fibers having a softening temperature greater than fibers of the fibrous batt layer;
disposing a thermosettable resin at interfacing surfaces between the fibrous batt layer and the reinforcing layer; and
thermoforming the layers into a porous three-dimensional configuration.

22. The method of claim 21, wherein the fibrous batt is comprised of thermoplastic fibers and the reinforcing layer comprises glass fibers, and wherein the thermosetable resin is selected from phenolic, urethane and melamine resins.

23. The method of claim 22, wherein the rigid foam layer comprises a rigid polyurethane foam.

24. The method of claim 23, wherein the fibrous batt layer is comprised of fibers having a length of from